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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES

208944US2PCT

DESIGNATED/ELECTED OFFICE (DO/EO/US)

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

CONCERNING A FILING UNDER 35 U.S.C. 371

09/856508

INTERNATIONAL APPLICATION NO.

PCT/FR99/03220

INTERNATIONAL FILING DATE

21 December 1999

PRIORITY DATE CLAIMED

23 December 1998

TITLE OF INVENTION

METHOD FOR RECEIVING SPECTRUM SPREADING SIGNALS WITH FREQUENCY SHIFT CORRECTION

APPLICANT(S) FOR DO/EO/US

BOULANGER Christophe et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☒ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Notice for Consideration of Documents Cited in International Search Report

Notice of Priority/PCT/IB/304/Drawings (9 Sheets)/PCT/IB/308

| | | |
|--|--|---|
| U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/856508 | INTERNATIONAL APPLICATION NO. PCT/FR99/03220 | ATTORNEY'S DOCKET NUMBER 208944US2PCT |
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|---|--------------|--------------|-----------|----------------------------------|----|
| 24. The following fees are submitted: | | | | CALCULATIONS PTO USE ONLY | |
| BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) : | | | | | |
| <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1000.00 | | | | | |
| <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$860.00 | | | | | |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$710.00 | | | | | |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$690.00 | | | | | |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 | | | | | |
| ENTER APPROPRIATE BASIC FEE AMOUNT = | | | | \$860.00 | |
| Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). | | | | \$0.00 | |
| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | | |
| Total claims | 5 - 20 = | 0 | x \$18.00 | \$0.00 | |
| Independent claims | 1 - 3 = | 0 | x \$80.00 | \$0.00 | |
| Multiple Dependent Claims (check if applicable). <input type="checkbox"/> | | | | \$0.00 | |
| TOTAL OF ABOVE CALCULATIONS = | | | | \$860.00 | |
| <input type="checkbox"/> Applicant claims small entity status. (See 37 CFR 1.27). The fees indicated above are reduced by 1/2. | | | | \$0.00 | |
| SUBTOTAL = | | | | \$860.00 | |
| Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). | | | | \$0.00 | |
| TOTAL NATIONAL FEE = | | | | \$860.00 | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). <input type="checkbox"/> | | | | \$0.00 | |
| TOTAL FEES ENCLOSED = | | | | \$860.00 | |
| | | | | Amount to be: refunded | \$ |
| | | | | charged | \$ |

- a. ☒ A check in the amount of **\$860.00** to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **15-0030**. A duplicate copy of this sheet is enclosed.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:



22850

WILLIAM E. BEAUMONT
REGISTRATION NUMBER 30,996

SIGNATURE

Marvin J. Spivak

NAME

24,913

REGISTRATION NUMBER

DATE

208944US

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: :

CHRISTOPHE BOULANGER ET AL. :

SERIAL NO: NEW APPLN. : ATTN: APPLICATION BRANCH

FILED: HEREWITH :

FOR: METHOD FOR RECEIVING
SPECTRUM SPREADING
SIGNALS WITH FREQUENCY
SHIFT CORRECTION

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE SPECIFICATION

Please amend the specification as shown in the marked-up copy following this amendment.

Please replace the paragraph at page 13, lines 6-9, with the following text:

In Fig. 9B, first of all, a correlation signal of channel I is seen before correction and affected by a Doppler effect. In Fig. 9A, this effect has been corrected.

Please replace the paragraph at page 13, lines 10-11, with the following text:

09/856508 JUN 15 2001

In Figs. 10B and 10A, the same signals are seen before and after correction, but on channel Q.

IN THE CLAIMS

Please amend Claims 1 and 3 as shown in the marked-up copy attached to read as follows:

1. (Amended) A method for receiving spectrum spreading signals with frequency shift correction, wherein:
 - a signal is received comprising a preamble made up of a sequence of known symbols spread in frequency by a pseudo-random sequence comprising N chips, followed by a sequence of information symbols spread in frequency by said pseudo-random sequence,
 - a base band signal is formed from the received signal,
 - a correlation is performed between the base band signal and the pseudo-random sequence at least in the portion of the signal corresponding to the information symbols in order to obtain a correlation signal,
 - a demodulation of the correlation signal is performed in order to obtain a demodulation signal,
 - the information symbols are restored, method wherein the correction of the frequency shift comprises the following steps:
 - a. in a first step, the correlation signal is processed in the portion corresponding to the preamble, in order to estimate the modulation period affecting this signal because of the frequency shift and a correcting signal with this estimated period is elaborated,

- b. in a second step, the signal is corrected before or after correlation in the portion corresponding to the information symbols, by means of said correcting signal,

this method being characterized in that:

- the base band signal, is divided into two components, a first component and a second component in quadrature with the first and a correlation is performed on each of these components in order to obtain two correlation components $CORR(I)$ and $CORR(Q)$,
- a DOT signal is calculated which is the sum of two direct products of successive samples of the correlation components, as well as a CROSS signal which is the difference between two crossed products of successive samples of the correlation components,
- for estimating the period of the modulation, the ratio between a CROSS signal and a DOT signal is calculated at each symbol period, the arc for which the tangent is equal to this ratio is calculated, the inverse of this arc is calculated and multiplied by $\pi N/2$.

3. (Amended) The method according to claim 1, wherein, in order to form the correction signal, a first component equal to $\cos(\pi x/2T)$ and a second component equal to $\sin(\pi x/2T)$ are formed, wherein x is a unit of time equal to kN , k is a number- assuming all the successive integer values and N is the number of chips of the pseudo-random sequence, and wherein T is the modulation period.

REMARKS

Favorable consideration of this application, as presently amended, is respectfully requested.

The present preliminary amendment is submitted to correct for minor informalities in the specification and Claims 1 and 3. The changes made to the specification and Claims 1 and 3 are deemed to be self-evident from the original disclosure, and thus are not deemed to raise any issues of new matter.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

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REGISTRATION NUMBER 30,996

Marked-Up Copy
Serial No:
HEREWITH
Amendment Filed on:
JUNE 15, 2001

IN THE SPECIFICATION

Please amend the specification as follows.

Please replace the paragraph at page 13, lines 6-9, with the following text:

--In Fig. [9A] 9B, first of all, a correlation signal of channel I is seen before correction and affected by a Doppler effect. In Fig. [9B] 9A, this effect has been corrected.--

Please replace the paragraph at page 13, lines 10-11, with the following text:

--In Figs. [10A] 10B and [10B] 10A, the same signals are seen before and after correction, but on channel Q.--

IN THE CLAIMS

Please amend Claims 1 and 3 as follows:

--1. (Amended) A method for receiving spectrum spreading signals with frequency shift correction, wherein:

- a signal is received comprising a preamble made up of a sequence of known symbols spread in frequency by a pseudo-random sequence comprising N chips, followed by a sequence of information symbols spread in frequency by said pseudo-random sequence,

- a base band signal is formed from the received signal,

- a correlation is performed between the base band signal and the pseudo-random sequence at least in the portion of the signal corresponding to the information symbols in order to obtain a correlation signal,

- a demodulation of the correlation signal is performed in order to obtain a demodulation signal,

- the information symbols are restored, method wherein the correction of the frequency shift comprises the following steps:

- a. in a first step, the correlation signal is processed in the portion corresponding to the preamble, in order to estimate the modulation period affecting this signal because of the frequency shift and a correcting signal with this estimated period $[T]$ is elaborated,
- b. in a second step, the signal is corrected before or after correlation in the portion corresponding to the information symbols, by means of said correcting signal,

this method being characterized in that:

- the base band signal, is divided into two components, a first component $[I]$ and a second component $[Q]$ in quadrature with the first and a correlation is performed on each of these components in order to obtain two correlation components $CORR(I)$ and $CORR(Q)$,
- a DOT signal is calculated which is the sum of two direct products of successive samples of the correlation components, as well as a CROSS signal which is the difference between two crossed products of successive samples of the correlation components,

- for estimating the period $[T]$ of the modulation, the ratio between a CROSS signal and a DOT signal is calculated at each symbol period, the arc for which the tangent is equal to this ratio is calculated, the inverse of this arc is calculated and multiplied by $\pi N/2$.

3. (Amended) The method according to claim 1, wherein, in order to form the correction signal, a first component $[(Cc)]$ equal to $\cos(\pi x/2T)$ and a second component $[(Cs)]$ equal to $\sin(\pi x/2T)$ are formed, wherein x is a unit of time equal to kN , k is a number- assuming all the successive integer values and N is the number of chips of the pseudo-random sequence, and wherein T is the modulation period.--

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METHOD FOR RECEIVING SPECTRUM SPREADING SIGNALS WITH
FREQUENCY SHIFT CORRECTION

Technical field

The object of the present invention is a method for receiving spectrum spreading signals with frequency shift correction. It finds an application in digital
5 transmissions.

With the invention, effects due to untimely frequency shifts may be corrected, regardless of the origin of these shifts. Most often, this will be a Doppler effect related to the moving speed of the
10 receiver. But this might also be effects due to a frequency shift of the local oscillators. In the description which follows, it will be assumed that the effect to be corrected is a Doppler effect, without however limiting the scope of the invention to this
15 case.

Prior state of the art

A great number of publications have been made on the correction of the Doppler effect. For example,
20 patent US-A-5 007 068 may be mentioned as well as the corresponding article of M. K. SIMON and D. DIVSALAR entitled "Doppler-Corrected Differential Detection of MPSK", published in the journal, "IEEE Transactions on Communications", Vol. 37, No. 2, February 1989, pages
25 99-109. These documents describe a technique wherein the Doppler shift is determined on one half of the symbol period. For this purpose, the receiver uses two circuits each with a half period delay, and a Doppler effect estimation circuit connected between the two
30 delay circuits. The correction is then performed on the

usual demodulated signal.

This technique may also be used for modulations of the multiple differential phase modulation type (abbreviated as MDPSK for "M-ary Differential Phase Shift Keying"), but it is not applicable to spectrum spreading transmissions where each symbol is multiplied by a pseudo-random sequence.

The article of F. D. NATALI, entitled "AFC Tracking Algorithms", published in the journal, "IEEE Transactions on Communications, vol. COM-32, No. 8, August 1984, pages 935-947, describes a technique in which preambles made up of known symbols are formed before transmitting the useful information. The working frequency is automatically controlled ("Automatic Frequency Control" or AFC) by a loop structure.

This technique is not adapted to the case when information data blocks separated by blanks are transmitted.

The following correction techniques may further be mentioned:

- the use of double detection, which gets rid of the Doppler effect by suitable encoding (US-A-4 481 640);

- the use of the frequency mixing principle in the radio portion of the receivers (US-A-4 706 286);

- the use of a phase locked loop (PLL) in the radio portion (US-A-4 841 544);

- the use of a dual mode with increased throughput (US-A-5 623 485).

These techniques are generally expensive and complex and do not make the most out of the advantages of spectrum spreading, nor of the digital processing of the signals. The object of the present invention is

precisely to overcome these drawbacks by providing a method which processes the signals in the base band (and not the signals in the radio portion) and which is well adapted to digital processing.

- 5 Document EP-A-0 822 668 describes a receiver for spectrum spreading signals wherein the Doppler effect correction is performed on the base band signal.

Description of the invention

- 10 Specifically, the object of the invention is a method for receiving spectrum spreading signals with frequency shift correction, wherein:

- a signal is received comprising a preamble made up from a sequence of known symbols spread in frequency by a pseudo-random sequence, followed by a sequence of information symbols spread in frequency by said pseudo-random sequence,

- a base band signal is formed from the received signal,

- a correlation is performed between the base band signal and the pseudo-random sequence at least in the portion of the signal corresponding to the information symbols, in order to obtain a correlation signal,

- a demodulation of the correlation signal is performed in order to obtain a demodulation signal,

- the information symbols are restored,
- a method wherein the frequency shift correction comprises the following steps:

- a. in a first step, the demodulation signal is processed in the portion corresponding to the preamble, in order to estimate the period of the modulation affecting the signal because of the frequency shift and a correcting signal

with this estimated period is elaborated,

- b. in a second step, the signal is corrected before or after the correlation in the portion corresponding to the information symbols, by means of said correcting signals,

the method being characterized in that:

- the base band signal is divided into two components, a first component (I) and a second component (Q) in quadrature with the first and a correlation is performed on each of these components in order to obtain two correlation components CORR (I) and CORR (Q),
- a DOT signal is calculated which is the sum of two direct products of successive samples of the correlation components, and a CROSS signal is calculated which is the difference between two crossed products of successive samples of the correlation components,
- in order to estimate the period (T) of the modulation, the ratio between a CROSS signal and a DOT signal is calculated at each symbol period, the arc is calculated for which the tangent is equal to this ratio, the inverse of this arc is calculated and multiplied by $\pi N/2$.

Brief description of the drawings

- Fig. 1 is a reminder of the general structure of a spreading spectrum signal receiver;
- Fig. 2 shows a correlation signal corresponding to a signal not affected by the Doppler effect;
- Fig. 3 shows this same signal affected by a slight Doppler effect;
- Fig. 4 shows this same signal but with a very

strong Doppler effect;

- Fig. 5 illustrates the sinusoidal modulation affecting a correlation signal because of the Doppler effect and it shows the period T of this modulation;
- Fig. 6 is a block diagram showing the estimation of the Doppler modulation from the DOT and CROSS demodulation signals;
- Fig. 7 illustrates an embodiment of a unit for estimating the modulation period and for forming the correction signal for the Doppler effect;
- Fig. 8 illustrates an embodiment of a correction circuit for the Doppler effect;
- Figs. 9A and 9B show a correlation signal before and after correction for the I channel;
- Figs. 10A and 10B show a correlation signal before and after correction for the Q channel;
- Figs. 11A and 11B show a correlation signal before and after correction on the I channel, with Gaussian noise;
- Figs. 12A and 12B show a correlation signal before and after correction on the Q channel, with Gaussian noise;
- Fig. 13 schematically illustrates the structure of a receiver with parallel suppression of interferences and weighting, with Doppler effect correction according to the invention;
- Fig. 14 shows the variations of the bit error rate versus the signal to noise ratio and enables the performances of a receiver according to the invention to be compared with other receivers of known types.

Description of the particular embodiments

Fig. 1 is a reminder of the general structure of a direct sequence spectrum spreading signal receiver. As an example, it is assumed that the modulation carried out at emission is a phase difference modulation. The receiver comprises means not shown such as an antenna and means for switching to base band, i.e. in order to multiply the received signal by a signal with the frequency of the carrier. The receiver generally includes two parallel channels, marked by indices I and Q, for the processing of a signal in phase with the carrier and a signal in phase quadrature with the latter. The illustrated receiver thus comprises two inputs $E(I)$, $E(Q)$, two analog-digital converters ADC(I), ADC(Q), two circuits $F(I)$, $F(Q)$ delivering two CORR(I) and CORR(Q) signals, a differential demodulation (DD) circuit delivering two signals, conventionally marked as "DOT" and "CROSS" (which are sums or differences of sample products at the correlation output), a circuit Inf/H restoring an information signal Sinf and a clock signal SH , and finally a decision circuit D, the output of which restores data d.

Circuits $F(I)$, $F(Q)$ perform a correlation operation between the received signal and the pseudo-random sequence used at emission. This operation consists in storing a certain number of successive samples and in performing a weighted sum with the help of coefficients which are the coefficients for direct sequence spectrum spreading. These coefficients are equal to +1 and to -1, according to the sign of the chips forming the pseudo-random sequence.

The analog-digital converters ADC(I) and ADC(Q)

operate at frequency $n_e F_c$ where F_c is the frequency of the chip ($F_c = 1/T_c$), and n_e is the number of samples taken in a chip period (T_c). To simplify the discussion, it will be assumed that one sample is taken
 5 per chip. The correlation signals $CORR(I)$ and $CORR(Q)$ contain one correlation peak per symbol period.

As for the DOT and CROSS signals delivered by the demodulation circuit DD, as a reminder, they are for the first, the sum $I_k I_{k-1} + Q_k Q_{k-1}$ and for the second, the
 10 difference $Q_k I_{k-1} - I_k Q_{k-1}$, where I_k and Q_k designate the correlation samples of rank k for channels I and Q, the rank corresponding to a symbol period (I_k corresponds to $CORR(I_k)$ and Q_k to $CORR(Q_k)$).

Fig. 2 shows the sequence of the correlation peaks
 15 in the ideal case of a preamble made up of binary data each equal to +1, the transmission being not affected by a Doppler effect. Fig. 2 relates both to channel I and channel Q. The time counted in chip periods appears on the abscissa. These peaks are separated from each
 20 other by N chips. In the illustrated case, $N = 31$. All the peaks have the same amplitude, in the ideal case, without any noise.

Fig. 3 illustrates the same case, but with a slight Doppler effect, while Fig. 4 illustrates the
 25 case of a strong Doppler effect. The frequency shift due to the Doppler effect is expressed by a phase shift of the processed signal and by a parasitic modulation of the correlation signal.

Fig. 5 resumes this matter in a more accurate way
 30 and shows the modulation related to the perturbation with its half-period marked as T , which is the time (counted in the number of chips) separating two successive extrema. The total period of the parasitic

modulation is therefore equal to $2T$. The method of the present invention enables this parasitic modulation to be corrected. According to the invention, this is carried out in two steps: first of all, the period T (or its double $2T$) is measured, so that a correction signal may be elaborated; then the signals are corrected by said correction signal.

In order to estimate the time T (or $2T$), according to the invention, the correlation signals are used as DOT and CROSS signals.

To carry out the correction, either the incident signals or the correlation signals are acted upon. There are therefore several possible alternatives which are illustrated in Figs. 6-8. In these figures, the notations have been slightly changed with respect to those of Fig. 1, in the sense that the signals before their processing bear a "DOP" index, to notify that they are affected by Doppler effect, the signals after processing being cleared of this index.

In Fig. 6, the Doppler effect estimation circuit EST_{dop} processes demodulation signals $DOT_{dop}(I)$ and/or $CROSS_{dop}(Q)$. Correction is carried out either on I_{dop} and Q_{dop} , or on $CORR_{dop}(I)$ and $CORR_{dop}(Q)$, in circuit CC_{dop} .

The properties of the signals to be processed are used for determining the period T illustrated in Fig. 5 (or $2T$). Indeed, it may be considered that the correlation signals corresponding to a preamble are made up of the samples of a cosine wave and of a sine wave of a half-period T , sampled every kN chips (cf. Fig. 5). This may therefore be written as:

$$CORR_{dop}(I_k) = P \cdot \cos(\pi kN/2T) \quad (1)$$

$$CORR_{dop}(Q_k) = P \cdot \sin(\pi kN/2T) \quad (2)$$

where P is an amplitude.

After differential demodulation, the following DOT and CROSS signals are obtained:

$$\text{DOT}_{\text{dop}}(k) = \text{CORR}_{\text{dop}}(I_k) \cdot \text{CORR}_{\text{dop}}(I_{k-1}) + \text{CORR}_{\text{dop}}(Q_k) \cdot \text{CORR}_{\text{dop}}(Q_{k-1}) \quad (3)$$

$$5 \quad \text{CROSS}_{\text{dop}}(k) = \text{CORR}_{\text{dop}}(Q_k) \cdot \text{CORR}_{\text{dop}}(I_{k-1}) - \text{CORR}_{\text{dop}}(I_k) \cdot \text{CORR}_{\text{dop}}(Q_{k-1}) \quad (4)$$

By replacing in (3), (4) the quantities with their values given by (1) and (2) and taking into account the properties of trigonometric functions, it is found
10 that:

$$\text{DOT}_{\text{dop}}(k) = P^2 \cdot \cos(\pi N/2T) \quad (5)$$

$$\text{CROSS}_{\text{dop}}(k) = P^2 \cdot \sin(\pi N/2T) \quad (6)$$

15 It is seen that both DOT_{dop} and $\text{CROSS}_{\text{dop}}$ quantities are independent of the rank k of the preamble symbol.

By taking the ratio of these quantities, the tangent of angle $\pi N/2T$ is formed from which the angle and the value of T may be extracted:

$$T = \frac{\pi \cdot N / 2}{\tan^{-1} \left(\frac{\text{CROSS}_{\text{dop}}(k)}{\text{DOT}_{\text{dop}}(k)} \right)} \quad (7)$$

where $\tan^{-1}(\cdot)$ means "arc for which the tangent is equal
25 to (\cdot) ".

The Doppler effect estimation circuit EST_{dop} of Fig. 6 is therefore simply a circuit comprising a divider for signals $A = \text{CROSS}_{\text{dop}}$ and $B = \text{DOT}_{\text{dop}}$, a circuit for calculating $\tan^{-1}(A/B)$, an inverter and a multiplier
30 by $N\pi/2$. T being known, a correction signal needs to be generated for which one component C_c is a cosine and the other C_s a sine:

$$C_c = \cos(\pi x/2T) \quad (8)$$

$$C_s = \sin(\pi x/2T) \quad (9)$$

Such a signal is generated by a generator with two quadrature outputs.

- 5 This calculation may be changed by taking a sequence of weighted samples and calculating:

$$T = \frac{\pi N/2}{\tan^{-1} \left[\frac{(1-\alpha) \sum_{k=0}^{\infty} \alpha^k CROSS_{dop}(k)}{(1-\alpha) \sum_{k=0}^{\infty} \alpha^k DOT_{dop}(k)} \right]} \quad (10)$$

- 15 Still in a more general way, estimation of T is improved by proceeding with low pass filtering of signals DOT_{dop} and $CROSS_{dop}$, i.e., with $A=f(CROSS_{dop}(k))$ and $B=f(DOT_{dop}(K))$, where f represents the filtering function:

$$T = \frac{\pi N/2}{\tan^{-1} \left[\frac{A}{2B} \right]} \quad (11)$$

A generator receiving T, delivers components C_s and C_c as defined by (8) and (9).

- 25 Fig. 7 illustrates a particular embodiment of the estimation circuit. This circuit comprises two amplifiers 10, 11 with gain $(1-\alpha)$, two multipliers 12, 13, the output of which is fed back to a second input as a loop by an amplifier 14, 15 via a delay line 16, 17. The circuit is completed by means for applying the
30 relation (11), i.e., a divider 20, a circuit 22 for calculating the arc tangent, a circuit 24 which calculates the inverse of the arc tangent, and an amplifier 26 with gain $\pi N/2$ which delivers quantity T.

A generator 30 receiving T delivers components Cc and Cs as defined by (8) and (9).

Having described the means for obtaining both components Cc and Cs of the correction signal, a description will now be made on how the received signals are corrected accordingly. This correction processes the signals carrying the transmitted information and no longer the preamble.

Generally, the correlation signals CORR(I) and CORR(Q) of the phase and quadrature channels may be considered as real and imaginary components of a complex signal $\text{CORR}(I) + j\text{CORR}(Q)$. The Doppler effect changes the phase of this signal (in other words, it rotates the vector which represents it) by a quantity $e^{j(\pi x/2T)}$. The obtained signal is the Doppler effect affected signal. Its components are $\text{CORR}_{\text{dop}}(I)$ and $\text{CORR}_{\text{dop}}(Q)$. This may be therefore written as:

$$\text{CORR}_{\text{dop}}(I) + j\text{CORR}_{\text{dop}}(Q) = [\text{CORR}(I) + j\text{CORR}(Q)]e^{j(\pi x/2T)} \quad (12)$$

Conversely, the components free from the Doppler effect may be expressed with respect to the components impaired by the Doppler effect as:

$$\text{CORR}(I) + j\text{CORR}(Q) = [\text{CORR}_{\text{dop}}(I) + j\text{CORR}_{\text{dop}}(Q)]e^{-j(\pi x/2T)} \quad (13)$$

By developing the right-hand member of this equation and by identifying the real and imaginary terms, it is found that:

30

$$\text{CORR}(I) = \text{CORR}_{\text{dop}}(I) \cos(\pi x/2T) + \text{CORR}_{\text{dop}}(Q) \sin(\pi x/2T) \quad (14)$$

$$CORR(Q) = CORR_{dop}(Q) \cdot \cos(\pi x / 2T) - CORR_{dop}(I) \cdot \sin(\pi x / 2T) \quad (15)$$

The same relationships may be established with
5 signals I and Q, i.e.:

$$[I + jQ] = [I_{dop} + jQ_{dop}] e^{-j(\pi x / 2T)} \quad (16)$$

i.e.:

$$I = I_{dop} \cdot \cos(\pi x / 2T) + Q_{dop} \cdot \sin(\pi x / 2T) \quad (17)$$

$$Q = Q_{dop} \cdot \cos(\pi x / 2T) - I_{dop} \cdot \sin(\pi x / 2T) \quad (18)$$

The correction circuit must therefore comprise
15 multipliers for multiplying the signals to be corrected
by both components of the correction signal, and adders
in order to perform the sum of the obtained products.
Fig. 8 shows an example of such a circuit. As
illustrated, it comprises two multipliers 41 and 42
20 receiving I_{dop} or $CORR_{dop}(I)$ and $\cos(\pi x / 2T)$ for the first
and Q_{dop} or $CORR_{dop}(Q)$ and $\sin(\pi x / 2T)$ for the second,
respectively, and an adder 43 connected to both
multipliers in order to deliver the signal from the
first channel corrected from the Doppler effect, i.e.,
25 I or $CORR(I)$. Similarly, the circuit further comprises
two multipliers 51 and 52 receiving Q_{dop} or $CORR_{dop}(Q)$
and $\cos(\pi x / 2T)$ for the first and I_{dop} or $CORR_{dop}(I)$ and
 $\sin(\pi x / 2T)$ for the second, respectively, and an adder
53 with an inverting input (in other words a
30 subtractor), the inverting input being connected to
multiplier 52 and the other input to multiplier 51.
This adder 53 delivers the signal of the second channel

corrected from the Doppler effect, i.e., Q or $CORR(Q)$.

Figs. 9A, 9B and 10A, 10C, on the one hand, as well as 11A, 11B and 12A, 12B, on the other hand, illustrate the correction which has just been
5 described.

In Fig. 9A, first of all, a correlation signal of channel I is seen before correction and affected by a Doppler effect. In Fig. 9B, this effect has been corrected.

10 In Figs. 10A and 10B, the same signals are seen before and after correction, but on channel Q.

Figs. 11A, 11B and 12A, 12B show the same signals but in the presence of noise such that a signal to noise ratio is 5 dB.

15 The invention is not limited to the case when both channel I and channel Q are corrected. One or the other of these channels might as well be corrected. The correction circuit will then implement the portion of the means required for calculating expressions (18)
20 or (19).

The invention, which has just been described, is applied to any type of pseudo-random sequence spectrum spreading signal receiver. In particular it may be applied to so-called Code Division Multiple Access
25 (CDMA) transmissions. In these transmissions, several users share a same channel by means of different pseudo-random sequences. The receiver then comprises as many parallel channels as users. In a particular embodiment, such a CDMA receiver may comprise parallel
30 suppression means for interference between users, with weighting means. Such a receiver is described in a French patent application filed by the present applicant on March 24th 1998, under number 98 03586.

Fig. 13 schematically illustrates such a receiver. As illustrated, it comprises a general input E , receiving a composite signal $R(t)$, K parallel channels V_1, V_2, \dots, V_K , where K is the maximum number of users, each channel delivering a signal $R_1(T), R_2(T), \dots, R_K(T)$, specific to each user, a weighted interference parallel suppression circuit (SPIP) and K decision circuits D_1, D_2, \dots, D_K , delivering data d_1, d_2, \dots, d_K , specific to each of the users.

Finally Fig. 14 enables the performances of a receiving method according to the invention to be compared with conventional methods. This figure 13 shows the variations of the bit error rate (BER) versus the signal to noise ratio SNR. Fig. 13 makes the assumption of $K = 5$ users with $N = 63$. The Doppler effect was simulated by a shift with respect to the carrier of the local oscillator.

Curve 50 refers to a conventional method with one stage, without interference suppression. Curves 51 and 52 refer to the same method but with two different Doppler effects, the first with a relative shift of 10^{-6} at 2.45 GHz and the second with a relative shift of 10^{-5} .

Curve 60 refers to an interference parallel suppression method with only one stage for parallel suppression of interferences and curves 61, 62 to the same method but with shifts of 10^{-6} and 10^{-5} .

Curve 70 refers to a method with two stages for parallel suppression of interferences with associated curves 71, 72 for shifts at 10^{-6} and 10^{-5} .

Finally, curve 80 marks the theoretical limit of the phase difference modulation technique (DQPSK).

CLAIMS

1. A method for receiving spectrum spreading signals with frequency shift correction, wherein:

- a signal is received comprising a preamble made up of a sequence of known symbols spread in frequency by a pseudo-random sequence, followed by a sequence of information symbols spread in frequency by said pseudo-random sequence,

- a base band signal is formed from the received signal,

- a correlation is performed between the base band signal and the pseudo-random sequence at least in the portion of the signal corresponding to the information symbols in order to obtain a correlation signal,

- a demodulation of the correlation signal is performed in order to obtain a demodulation signal,

- the information symbols are restored,

a method wherein the correction of the frequency shift comprises the following steps:

a. in a first step, the correlation signal is processed in the portion corresponding to the preamble, in order to estimate the modulation period affecting this signal because of the frequency shift and a correcting signal with this estimated period (T) is elaborated,

b. in a second step, the signal is corrected before or after correlation in the portion corresponding to the information symbols, by means of said correcting signal,

this method being characterized in that:

• the base band signal is divided into two components, a first component (I) and a second

component (Q) in, quadrature with the first and a correlation is performed on each of these components in order to obtain two correlation components CORR(I) and CORR(Q),

5 • a DOT signal is calculated which is the sum of two direct products of successive samples of the correlation components, as well as a CROSS signal which is the difference between two crossed products of successive samples of the correlation components,

10 • for estimating the period (T) of the modulation, the ratio between a CROSS signal and a DOT signal is calculated at each symbol period, the arc for which the tangent is equal to this ratio is calculated, the inverse of this arc is calculated and multiplied by $\pi N/2$.

20 2. The method according to claim 1, wherein the CROSS and DOT signals are first filtered by low pass filtering.

25 3. The method according to claim 1 or 2, wherein, in order to form the correction signal, a first component (Cc) equal to $\cos(\pi x/2T)$ and a second component (Cs) equal to $\sin(\pi x/2T)$ are formed, wherein x is a unit of time equal to kN, k is a number assuming all the successive integer values and N is the number of items of the pseudo-random sequence, and wherein T is the modulation period.

30 4. The method according to claim 3, wherein the base band signals of the first and/or second channels

i.e., I_{dop} and Q_{dop} , are corrected by calculating a first quantity equal to:

$$I_{\text{dop}}.\cos(\pi x/2T) + Q_{\text{dop}}.\sin(\pi x/2T),$$

5

which gives a signal I specific to the first channel corrected from the frequency shift and/or by calculating a second quantity equal to:

$$Q_{\text{dop}}.\cos(\pi x/2T) - I_{\text{dop}}.\sin(\pi x/2T),$$

10

which gives a signal (Q) specific to the second channel corrected from the frequency shift.

15 5. The method according to claim 3, wherein the correlation signals of the first and/or second channels, i.e., $\text{CORR}_{\text{dop}}(I)$ and $\text{CORR}_{\text{dop}}(Q)$ are corrected by calculating a first quantity equal to:

$$20 \quad \text{CORR}_{\text{dop}}(I).\cos(\pi x/2T) + \text{CORR}_{\text{dop}}(Q).\sin(\pi x/2T),$$

which gives a correlation signal $\text{CORR}(I)$ specific to the first channel corrected from the frequency shift and/or by calculating a second quantity equal to:

25

$$\text{CORR}_{\text{dop}}(Q).\cos(\pi x/2T) - \text{CORR}_{\text{dop}}(I).\sin(\pi x/2T),$$

which gives a correlation signal $\text{CORR}(Q)$ specific to the second channel corrected from the frequency shift.

30

DESCRIPTIVE ABSTRACT

Method for receiving spectrum spreading signals with frequency shift correction.

- According to the invention, the modulation period related to the Doppler effect is estimated by using a preamble and a correction signal is elaborated, the
5 signal transmitting the information is then corrected by this correction signal. Base band digital signals are operated upon by using the DOT and CROSS components.
- 10 Application to digital transmissions.

Fig. 6.

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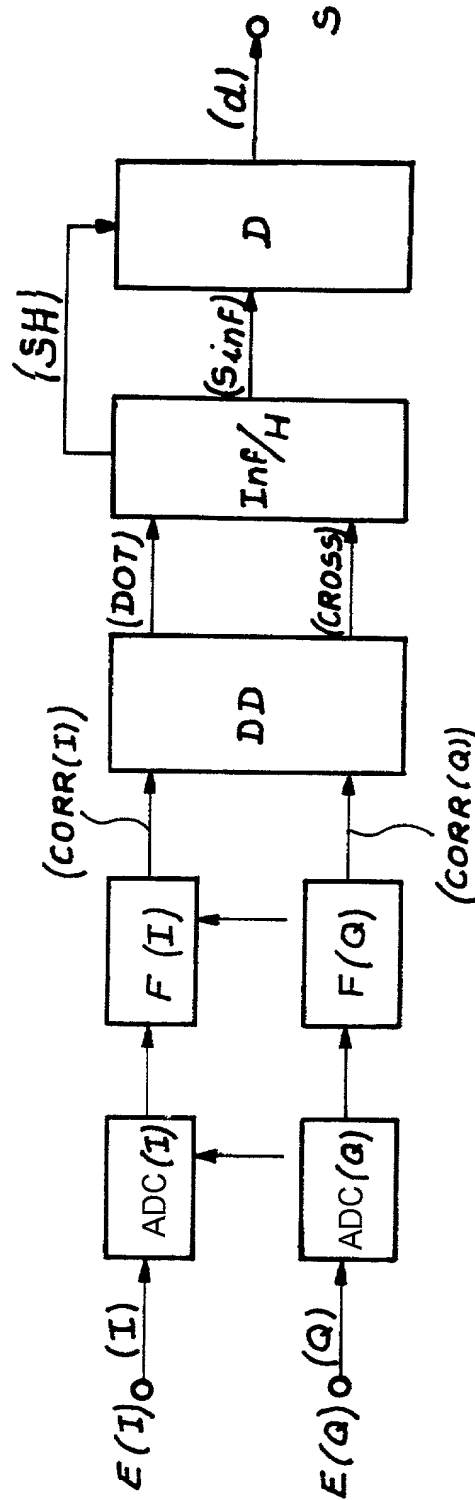


FIG. 1

FIG. 1

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FIG. 2

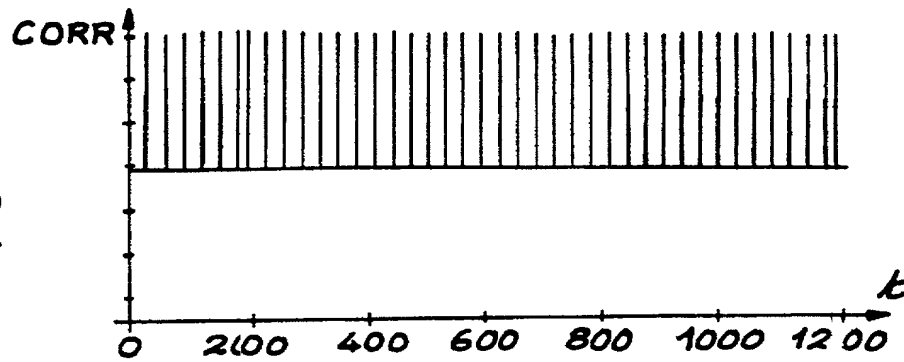


FIG. 3

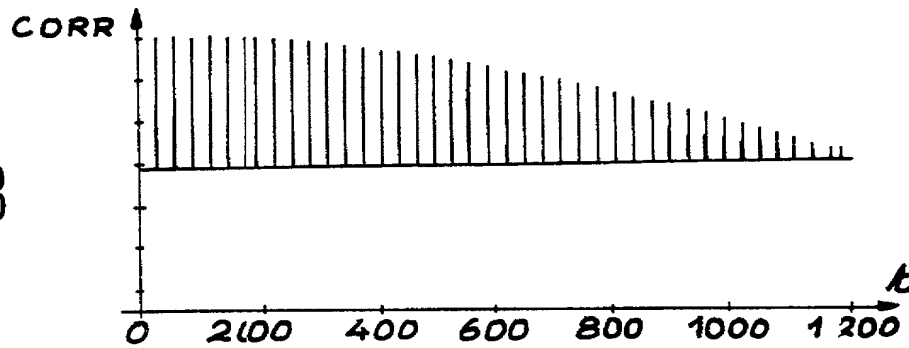


FIG. 4

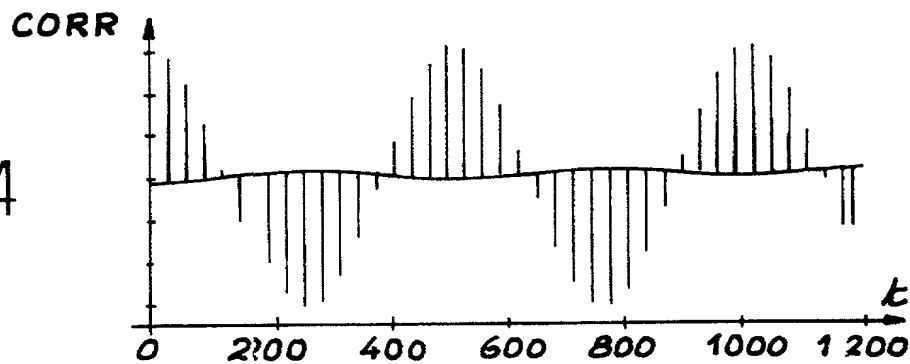
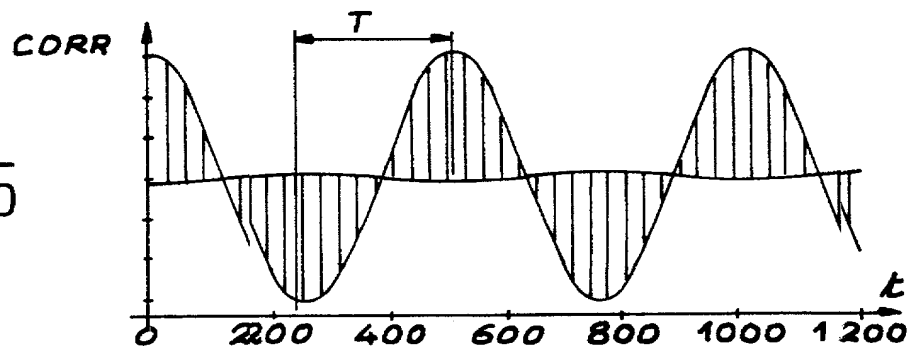


FIG. 5



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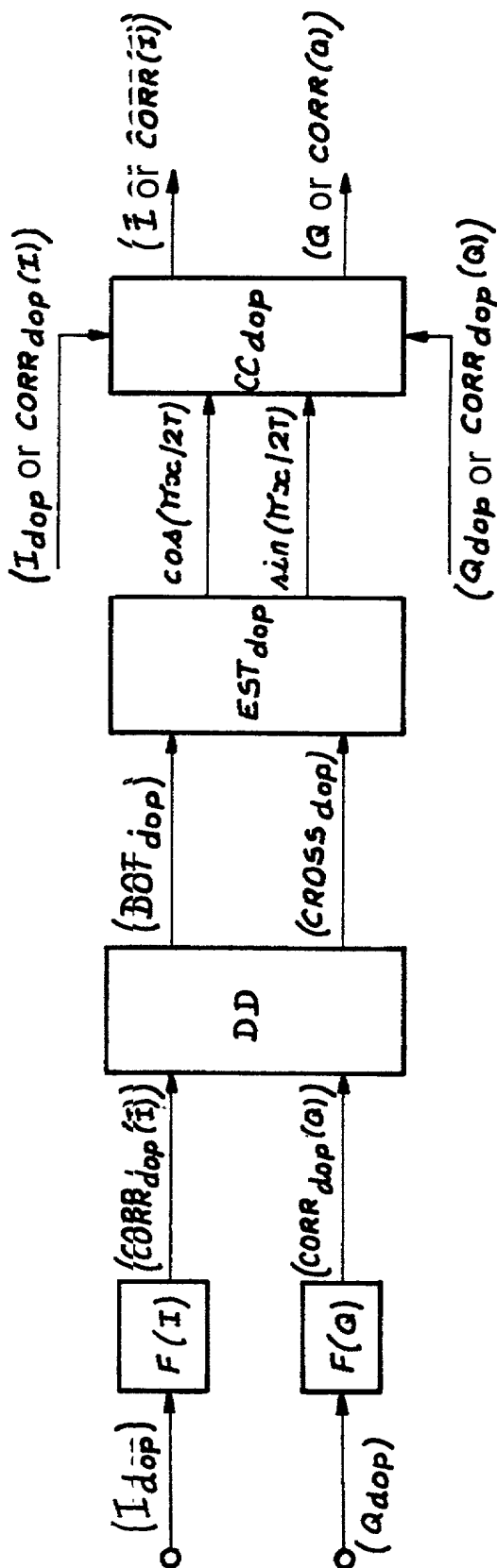
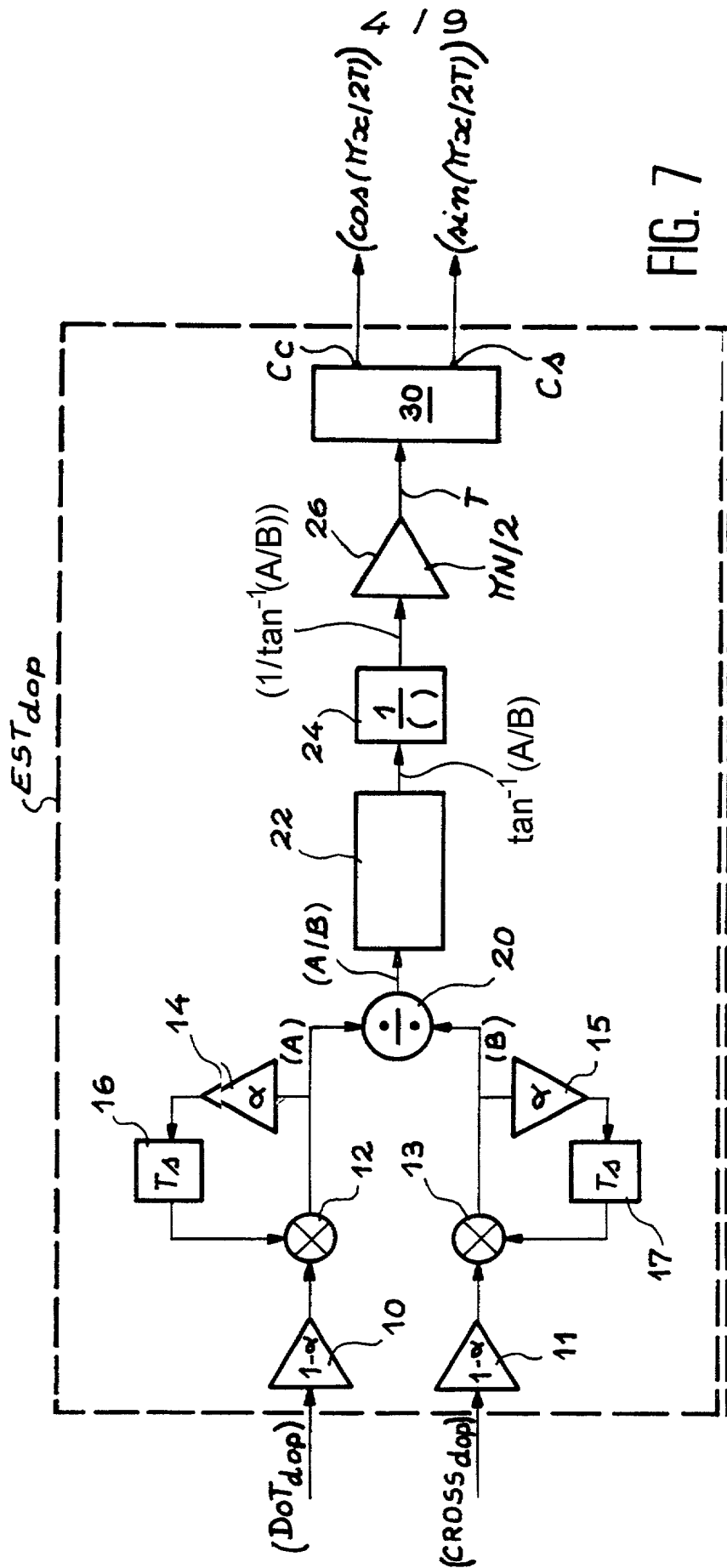


FIG. 6

| Variable | Mean | SD | Min | Max |
|-----------------------|--------------|----------|---------|----------|
| Age | 38.5 | 12.5 | 25 | 65 |
| Gender | Male | 100% | | |
| Marital status | Married | 100% | | |
| Education | High school | 100% | | |
| Occupation | Teacher | 100% | | |
| Income | \$10,000 | \$10,000 | \$5,000 | \$15,000 |
| Health status | Good | 100% | | |
| Smoking status | Non-smoker | 100% | | |
| Alcohol consumption | None | 100% | | |
| Exercise frequency | None | 100% | | |
| Stress level | Low | 100% | | |
| Sleep quality | Good | 100% | | |
| Dietary habits | Healthy | 100% | | |
| Family size | 2 | 1 | 1 | 3 |
| Religious beliefs | Christian | 100% | | |
| Political views | Conservative | 100% | | |
| Travel frequency | None | 100% | | |
| Pets | None | 100% | | |
| Volunteering | None | 100% | | |
| Charitable donations | None | 100% | | |
| Community involvement | None | 100% | | |
| Life satisfaction | High | 100% | | |
| Overall well-being | Excellent | 100% | | |



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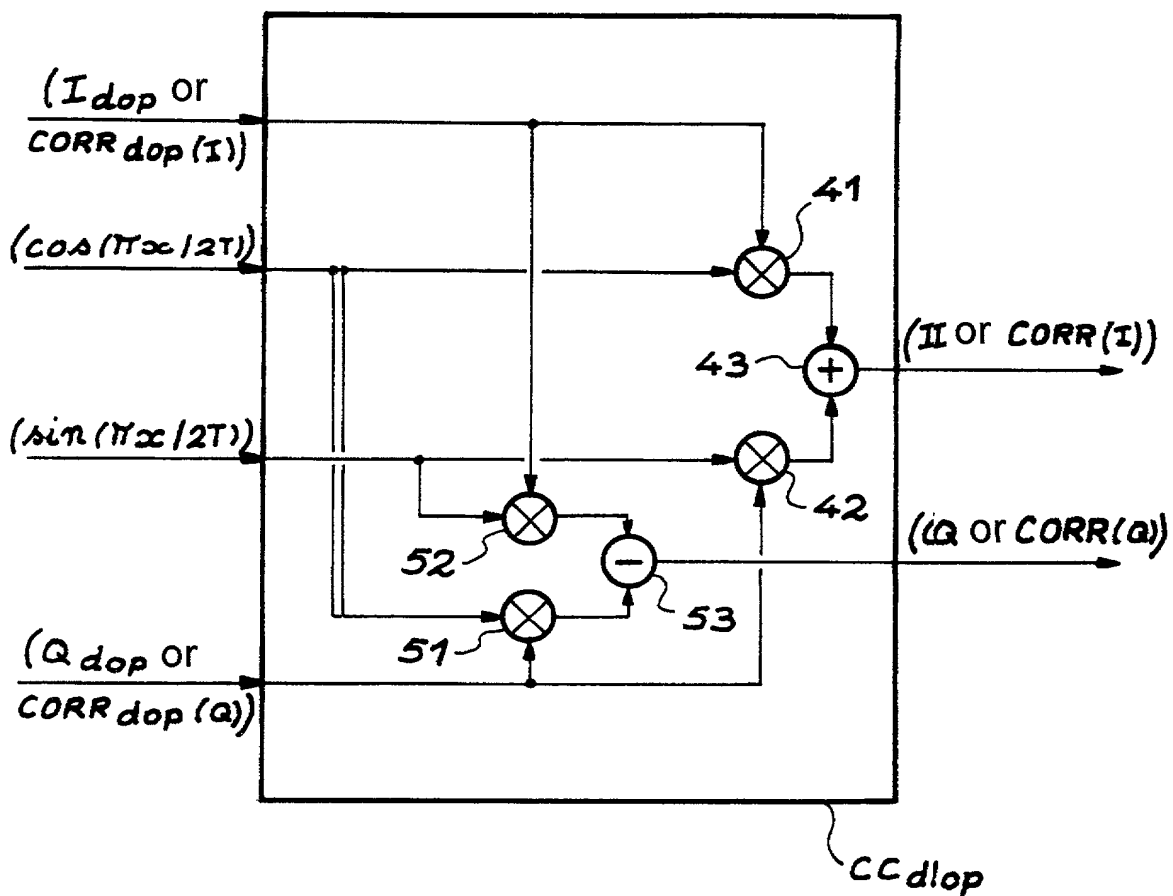
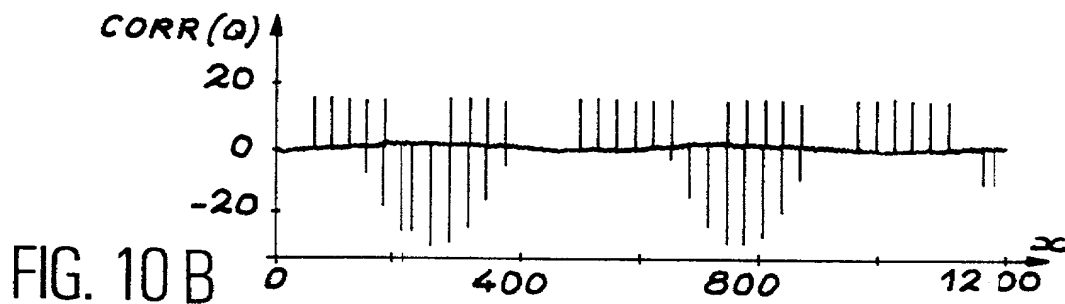
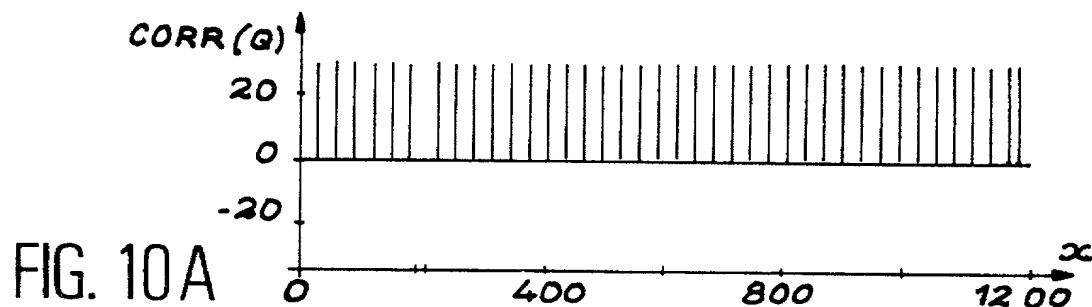
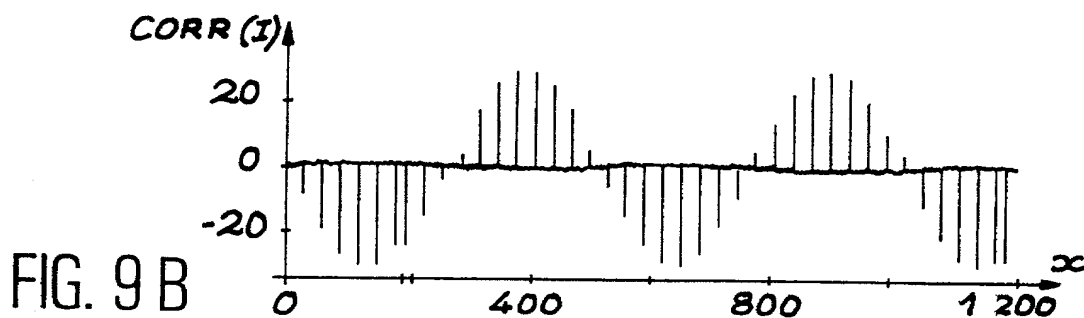
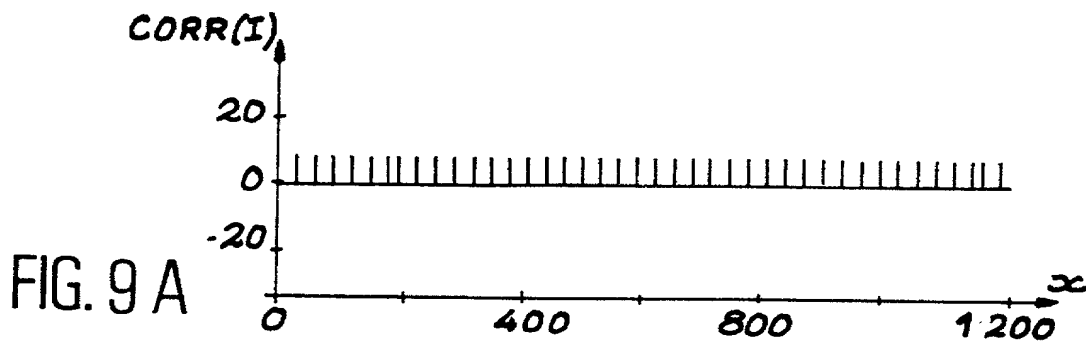


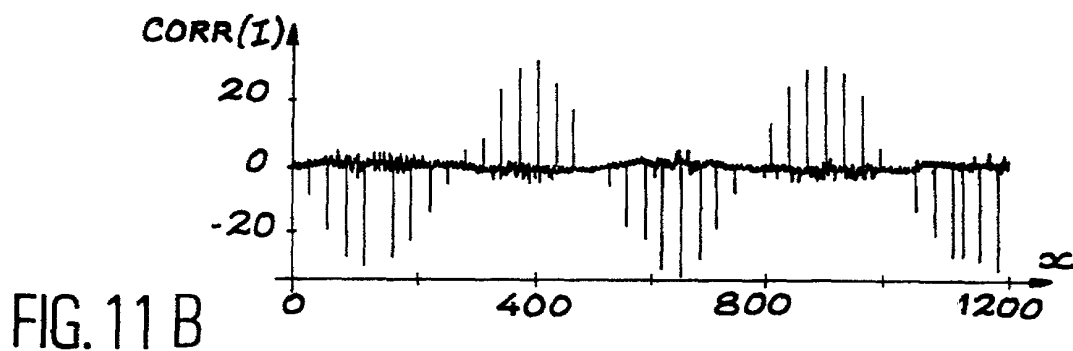
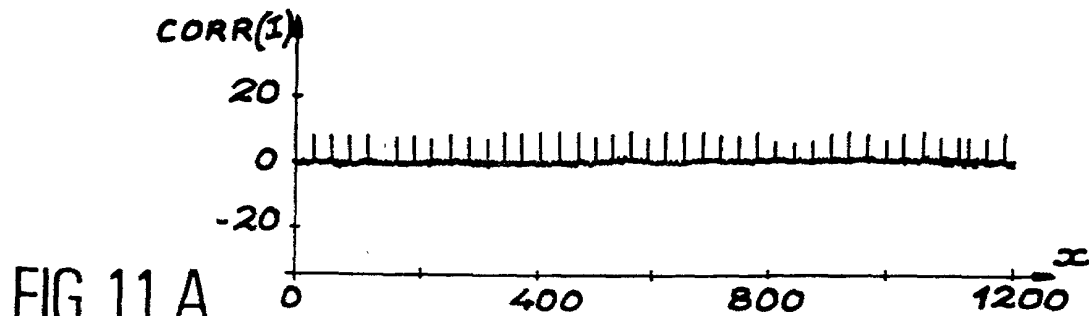
FIG. 8

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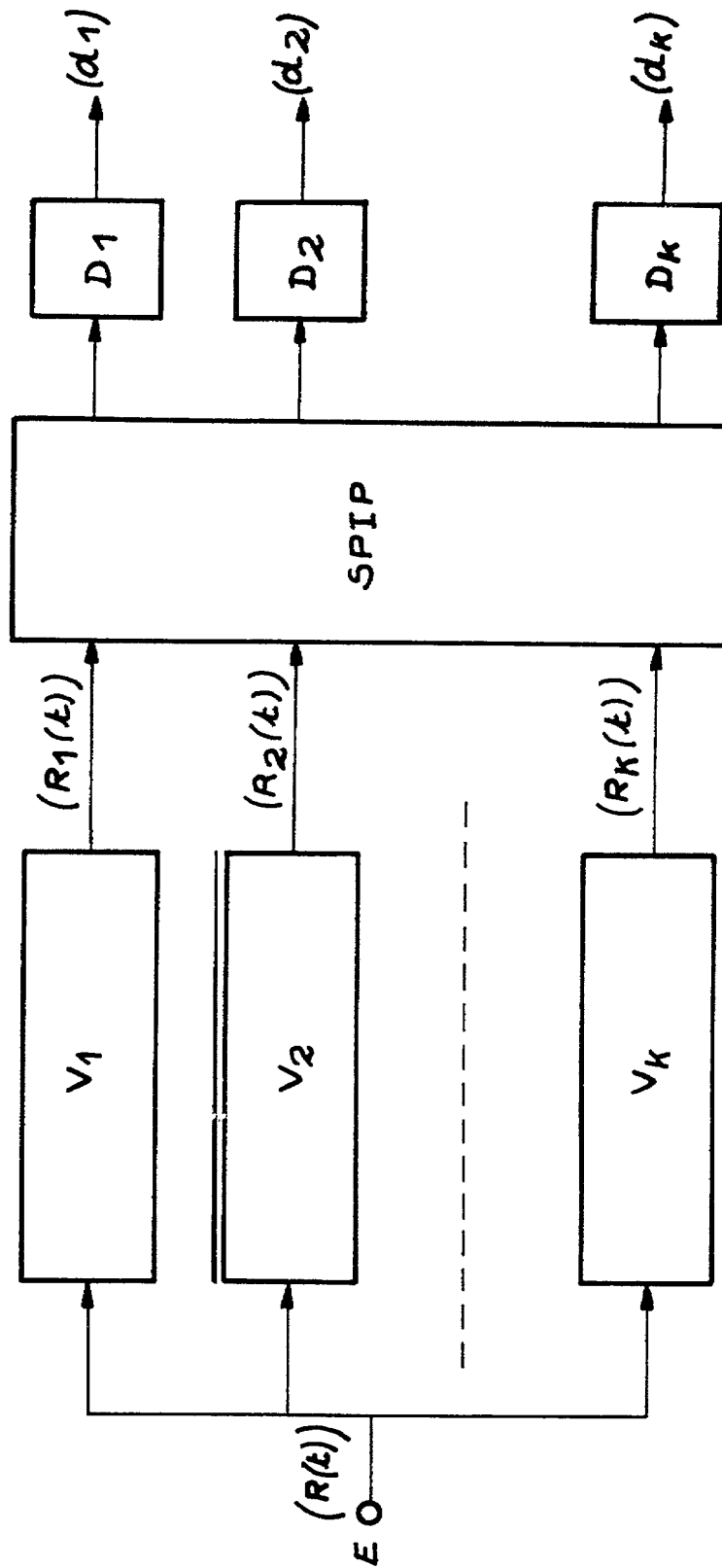


FIG. 13

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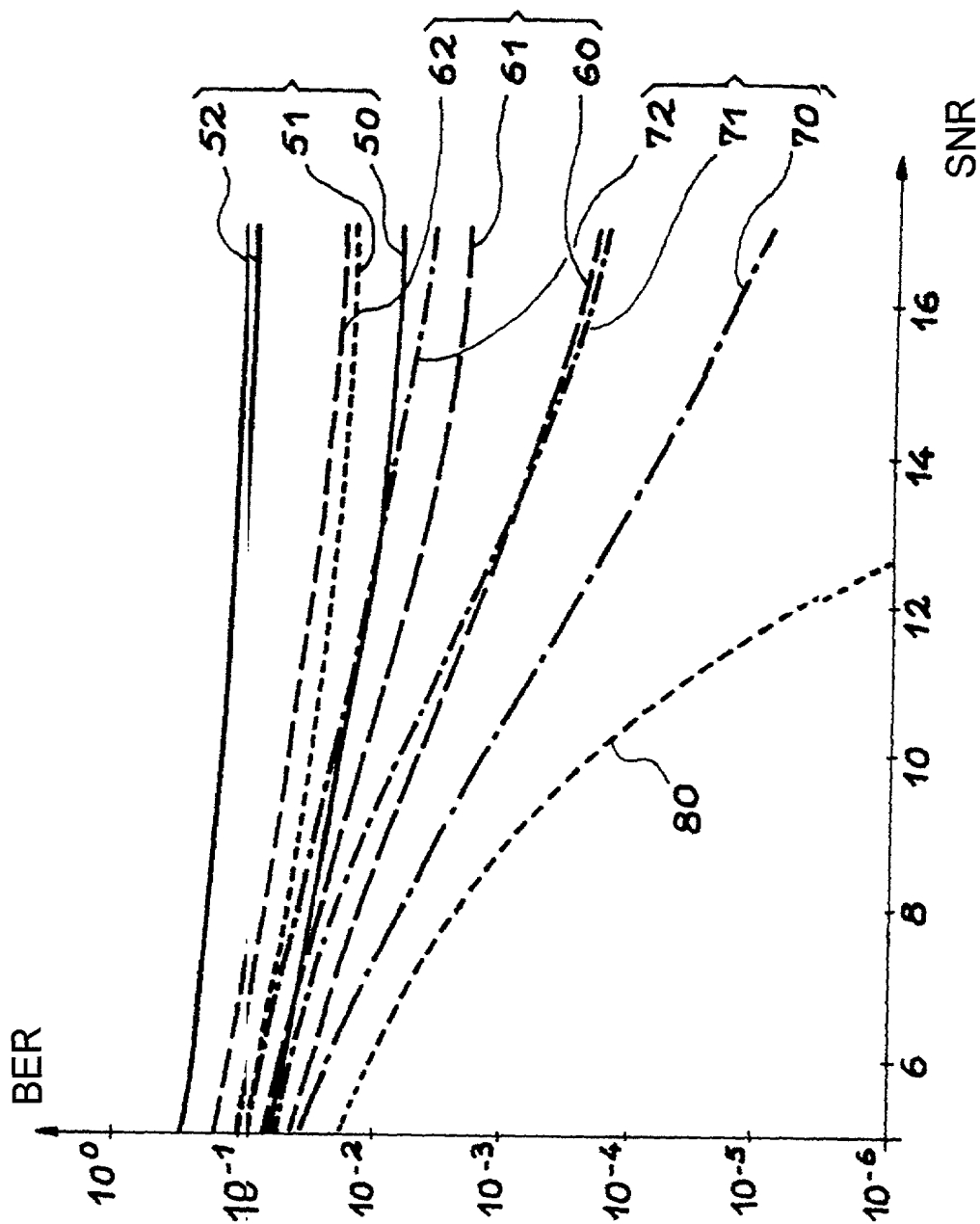


FIG. 14

Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD FOR RECEIVING SPECTRUM SPREADING SIGNALS WITH FREQUENCY SHIFT CORRECTION

The specification of which

- ☐ is attached hereto.
- ☐ was filed on
as Application Serial No.
and amended on
- ☒ was filed as PCT international application
Number PCT/FR99/03220
on December 21, 1999
and was amended under PCT Article 19
on

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

| Application No. | Country | Day/month/Year | Priority Claimed | |
|-----------------|---------|------------------|---|-----------------------------|
| 98 16316 | FRANCE | 23 DECEMBER 1998 | <input checked="" type="checkbox"/> YES | <input type="checkbox"/> NO |
| _____ | _____ | _____ | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| _____ | _____ | _____ | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| _____ | _____ | _____ | <input type="checkbox"/> YES | <input type="checkbox"/> NO |

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number)

(Filing Date)

(Application Number)

(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.

Filing Date


Status (pending, patented,
abandoned)

And we (I) hereby appoint : Norman F. Oblon, Registration Number 24,618; Marvin J. Spivak, Registration Number 24,913; C. Irvin McClelland, Registration Number 21,214; Gregory J. Maier, Registration Number 25,599; Arthur I. Neustadt, Registration Number 24,854; Richard D. Kelly, Registration Number 27,757; James D. Hamilton, Registration Number 28,421; Eckhard H. Kuesters, Registration Number 28,870; Robert T. Pous, Registration Number 29,099; Charles L. Gholz, Registration Number 26,395; Vincent J. Sunderdick, Registration Number 29,004; William E. Beaumont, Registration Number 30,996; Steven B. Kelber, Registration Number 30,073; Robert F. Gnuse, Registration Number 27,295; Jean-Paul Lavalleye, Registration Number 31,451; William B. Walker, Registration Number 22,498; Timothy R. Schwartz, Registration Number 32,171; Stephen G. Baxter, Registration Number 32,884; Martin M., Zoltick, Registration Number 35,745; Robert W. Hahl, Registration Number 33,893; and Richard L. Treanor, Registration Number 36,379; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C., whose post Office Address is : Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and future that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

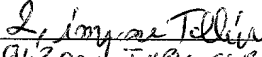
100 BOULANGER Christophe

NAME OF FIRST SOLE INVENTOR


Signature of Inventor

May 15, 2001

Date

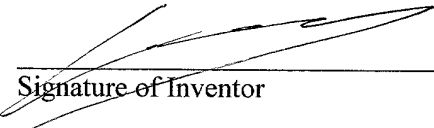
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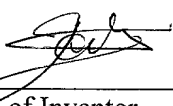
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NAME OF FIFTH INVENTOR

Signature of Inventor

Date

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Citizen of : _____

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